CLAIMS

We claim:

1. A method for forming a thermal barrier coating system in communication with at least a portion of at least one substrate, the method comprising:

presenting said at least one substrate to a chamber, wherein said chamber has a down stream pressure, P_c, with an operating range from about 0.0001 Pa to about 150 Pa;

depositing a bond coat on at least a portion of at least one said substrate;

presenting at least one evaporant source to said chamber;

presenting at least one carrier gas stream to said chamber, wherein said at least one carrier gas stream is generated from at least one nozzle;

impinging at least one said evaporant source with at least one energetic beam in said chamber to generate an evaporated vapor flux in a main direction respective for any of said evaporant sources impinged by said energetic beam, said at least one evaporant source is disposed in said nozzle;

said at least one carrier gas stream has a pressure ratio in the operating range from about 1.01 to about 10,000,000;

said substrate having a temperature approximately equal to or greater than a melting point of said substrate;

said at least one evaporant source generates said evaporated vapor flux and an evaporation rate in the range of about 0.00001 g/min to about 100,000 g/min; and

deflecting at least one of said generated evaporated vapor flux by at least one of said carrier gas stream, wherein said carrier gas stream is essentially parallel to the main direction and substantially surrounds said evaporated flux, wherein said evaporated vapor flux at least partially coats at least one said substrate.

2. The method of claim 1, wherein said substrate having a temperature in the range of about 25° C to about 1,250° C.

3. The method of claim 1, wherein:

said down stream pressure, P_c, has an operating range from about 0.1 Pa to about 20 Pa;

said at least one carrier gas stream has a pressure ratio in the operating range from about 1.01 to about 1,000; and

said substrate having a temperature approximately equal to or greater than a melting point of said substrate.

4. The method of claim 3, wherein said substrate having a temperature in the range of about 900° C to about 1,250° C.

5. The method of claim 1, wherein:

said down stream pressure, P_c, has an operating range from about 1 Pa to about 20 Pa;

said at least one carrier gas stream has a pressure ratio in the operating range from about 11 to about 1,000; and

said substrate having a temperature approximately equal to or greater than a melting point of said substrate.

6. The method of claim 5, wherein said substrate having a temperature in the range of about 900° C to about 1,250° C.

7. The method of any one of claims 1, 2, 3, 4, 5 and 6, wherein said at least one substrate is held stationary during the deposition process.

8. The method of any one of claims 1, 2, 3, 4, 5 and 6, wherein said at least one substrate is moved during at least a portion of the deposition process.

9. The method of claim 8, wherein the movement comprises at least a partial

rotation or multiple rotations.

10. The method of any one of claims 1, 2, 3, 4, 5 and 6, wherein said at least one evaporant source has a diameter in the range of about 0.1 inch to about 10 inch.

11. The method of claim 10, wherein said at least one evaporant source has a diameter in the range of about 0.5 inch to about 1 inch.

12. The method of anyone of claims 3 and 4, wherein said evaporation rate in the range of about 0.1 g/min to about 100 g/min.

13. The method of any one of claims 12, wherein said at least one evaporant source has a diameter in the range of about 0.1 inch to about 10 inch.

14. The method of claim 13, wherein said at least one evaporant source has a diameter in the range of about 0.5 inch to about 1 inch.

15. The method of anyone of claims 5 and 6, wherein said evaporation rate in the range of about 0.1 g/min to about 100 g/min.

16. The method of any one of claims 15, wherein said at least one evaporant source has a diameter in the range of about 0.1 inch to about 10 inch.

17. The method of claim 16, wherein said at least one evaporant source has a diameter in the range of about 0.5 inch to about 1 inch.

18. The method of anyone of claims 1, 2, 3, 4, 5 and 6, wherein said evaporant source comprises at least one of Zirconium, Hafnium, mullite, alumina, silica, any oxide ceramic, ceria, zirconate, garnet, lanthanum aluminate, titania, any carbide, silicide or combination thereof.

19. The method of anyone of claims 1, 2, 3, 4, 5 and 6, wherein said evaporant source comprises at least one of any ceramic material or combination thereof.

20. The method of anyone of claims 1, 2, 3, 4, 5 and 6, wherein said evaporants have substantially the same chemical composition relative to one another.

21. The method of anyone of claims 1, 2, 3, 4, and 6, wherein said evaporants have different chemical composition relative to one another.

22. A method for forming a thermal barrier coating system, the method comprising:

presenting a substrate to a chamber, wherein said chamber has a down stream pressure, P_c, with an operating range from about 5 Pa to about 50 Pa;

depositing a bond coat on at least a portion of at least one said substrate;

presenting at least one evaporant source to said chamber;

presenting at least one carrier gas stream to said chamber, wherein said at least one carrier gas stream is generated from at least one nozzle;

impinging at least one said evaporant source with at least one energetic beam in said chamber to generate an evaporated vapor flux in a main direction respective for any of said evaporant sources impinged by said energetic beam, said at least one evaporant source is disposed in said nozzle;

said at least one carrier gas stream has a pressure ratio in the operating range from about 1 to about 100;

said substrate having a temperature in the range of about 15° C and about 1,250° C;

said at least one evaporant source generates said evaporated vapor flux and an evaporation rate in the range of about 0.1 g/min to about 100 g/min;

deflecting at least one of said generated evaporated vapor flux by at least one of said carrier gas stream, wherein said carrier gas stream is essentially parallel to the main direction and substantially surrounds said evaporated flux, wherein said evaporated vapor flux at least partially coats at least one said substrate;

said chamber further includes a substrate bias system capable of applying a DC or alternating potential to at least one of said substrates;

impinging said at least one of said generated vapor flux and at least one of said carrier gas stream with a working gas generated by at least one hollow cathode arc plasma activation source to ionize said at least one of said generated vapor flux and at least one of said carrier gas stream; and

attracting said ionized generated vapor flux and said carrier gas stream to a substrate surface by allowing a self-bias of said ionized gas and vapor stream or said potential to pull the ionized stream to said substrate.

23. The method of claim 22, wherein said substrate having a temperature in the range of about 300° C and about 1,250° C.

24. The method of claim 22, wherein said substrate having a temperature in the range of about 600° C and about 1,250° C.

25. The method of claim 22, wherein said substrate having a temperature in the range of about 900° C and about 1,250° C.

26. The method of any one of claims 22, 23, 24 and 25, wherein said at least

one evaporant source has a diameter in the range of about 0.1 inch to about 10 inch.

27. The method of claim 26, wherein said at least one evaporant source has a diameter in the range of about 0.5 inch to about 1 inch.

28. The method of claim 22, said generated electrons from said hollow cathode source is regulated for direction through variations in the quantity of working gas passing through said hollow cathode source.

29. The method of claim 22, wherein the distance between said cathode source and said generated evaporated vapor flux is regulated for ionization of the entire generated evaporated vapor flux.

30. The method of any one of claims 22, 23, 24 and 25, wherein said at least one substrate is held stationary.

31. The method of any one of claims 22, 23, 24 and 25, wherein said at least one substrate is moved during at least a portion of the vapor flux coating .

32. The method of claim 31, wherein the movement comprises at least a partial rotation or multiple rotations.

33. The method of anyone of claims 22, 23, 24 and 25, wherein said evaporant source comprises at least one of Zirconium, Hafnium, mullite, alumina, silica, any oxide ceramic, ceria, zirconate, garnet, lanthanum aluminate, titania, any carbide, silicide and/or other ceramics, or combination thereof.

34. The method of anyone of claims 22, 23, 24 and 25, wherein said evaporant source comprises at least one of any ceramic material or combination thereof.

35. The method of anyone of claims 22, 23, 24 and 25, wherein said evaporants have substantially the same chemical composition relative to one another.

36. The method of anyone of claims 22, 23, 24 and 25, wherein said evaporants have different chemical composition relative to one another.

37. The method of claim 1 or 22, wherein said energetic beam comprises at least one of electron beam source, laser source, heat source, ion bombardment source, highly focused incoherent light source, microwave, radio frequency, EMF, or any energetic beam that break chemical bonds, or any combination thereof.

38. The method of claim 1 or 22, wherein said communication with said substrate is direct or indirect.

39. An apparatus for applying a thermal barrier coating system in communication with at least a portion of at least one substrate, said apparatus comprising:

a chamber, wherein said chamber has a down stream pressure, P_c, with an operating range from about 0.0001 Pa to about 150 Pa;

at least one evaporant source disposed in said chamber, said at least one evaporant source generates said evaporated vapor flux and an evaporation rate in the range of about 0.00001 g/min to about 100,000 g/min;

at least one carrier gas stream provided in said chamber, wherein said at least one carrier gas stream is generated from at least one nozzle, said at least one carrier gas stream has a pressure ratio in the operating range from about 1.01 to about 10,000,000; and

at least one energetic beam, said energetic beam:

impinging at least one said evaporant source with at least one energetic beam in said chamber to generate an evaporated vapor flux in a main direction respective for any of said evaporant sources impinged by said energetic beam,

deflecting at least one of said generated evaporated vapor flux by at least one of said carrier gas stream, wherein said carrier gas stream is essentially parallel to the main direction and substantially surrounds said evaporated flux, wherein said evaporated vapor flux at least partially coats at least one said substrate, and

said substrate having a temperature approximately equal to or greater than a melting point of said substrate.

40. The apparatus of claim 39, wherein said substrate having a temperature in the range of about 25° C to about 1,250° C.

41. The apparatus of claim 39, wherein

said down stream pressure, P_c, has an operating range from about 0.1 Pa to about 20 Pa;

said at least one carrier gas stream has a pressure ratio in the operating range from about 1.01 to about 1,000; and

said substrate having a temperature approximately equal to or greater than a melting point of said substrate.

42. The apparatus of claim 41, wherein said substrate having a temperature in the range of about 900° C to about 1,250° C.

43. The apparatus of claim 39, wherein

said down stream pressure, P_c, has an operating range from about 1 Pa to about 20 Pa;

said at least one carrier gas stream has a pressure ratio in the operating range from

about 11 to about 1,000; and

said substrate having a temperature approximately equal to or greater than a melting point of said substrate.

44. The apparatus of claim 43, wherein said substrate having a temperature in the range of about 900° C to about 1,250° C.

45. The apparatus of any one of claims 39, 40, 41, 42, 43 and 44, wherein said at least one substrate is held stationary during the deposition process.

46. The apparatus of any one of claims 39, 40, 41, 42, 43 and 44, wherein said at least one substrate is moved during at least a portion of the deposition process.

47. The apparatus of claim 46, wherein the movement comprises at least a partial rotation or multiple rotations.

48. The apparatus of anyone of claims 39, 40, 41, 42, 43 and 44, wherein said evaporant source comprises at least one of Zirconium, Hafnium, mullite, alumina, silica, any oxide ceramic, ceria, zirconate, garnet, lanthanum aluminate, titania, any carbide, silicide or combination thereof.

49. The apparatus of anyone of claims 39, 40, 41, 42, 43 and 44, wherein said evaporant source comprises at least one of any ceramic material or combination thereof.

50. The apparatus of anyone of claims 39, 40, 41, 42, 43 and 44, wherein said evaporants have substantially the same chemical composition relative to one another.

51. The apparatus of anyone of claims 39, 40, 41, 42, 43 and 44, wherein said evaporants have different chemical composition relative to one another.

52. An apparatus for applying a thermal barrier coating system in communication with at least a portion of at least one substrate, said apparatus comprising:

a chamber, wherein said chamber has a down stream pressure, P_c, with an operating range from about 5 Pa to about 50 Pa;

at least one evaporant source disposed in said chamber, said at least one evaporant source generates said evaporated vapor flux and an evaporation rate in the range of about 0.1 g/min to about 100 g/min;

at least one carrier gas stream provided in said chamber, wherein said at least one carrier gas stream is generated from at least one nozzle, said at least one carrier gas stream has a pressure ratio in the operating range from about 1 to about 100;

at least one energetic beam, said energetic beam:

impinging at least one said evaporant source with at least one energetic beam in said chamber to generate an evaporated vapor flux in a main direction respective for any of said evaporant sources impinged by said energetic beam,

deflecting at least one of said generated evaporated vapor flux by at least one of said carrier gas stream, wherein said carrier gas stream is essentially parallel to the main direction and substantially surrounds said evaporated flux, wherein said evaporated vapor flux at least partially coats at least one said substrate, and

said substrate having a temperature approximately equal to or greater than a melting point of said substrate; and

a substrate bias system capable of applying a DC or alternating potential to at least one of said substrates; and

at least one hollow cathode arc source generating a low voltage beam, said at least one hollow cathode arc source:

impinging said at least one of said generated vapor flux and at least one of said carrier gas stream with a working gas generated by at least one said hollow

cathode arc plasma activation source to ionize said at least one of said generated vapor flux and at least one of said carrier gas stream; and

attracting said ionized generated vapor flux and said carrier gas stream to a substrate surface by allowing a self-bias of said ionized gas and vapor stream or said potential to pull the ionized stream to said substrate.

53. The apparatus of claim 52, wherein said substrate having a temperature in the range of about 300° C and about 1,250° C.

54. The apparatus of claim 52, said generated electrons from said hollow cathode source is regulated for direction through variations in the quantity of working gas passing through said hollow cathode source.

55. The apparatus of claim 52, wherein the distance between said cathode source and said generated evaporated vapor flux is regulated for ionization of the entire generated evaporated vapor flux.

56. The apparatus of claim 39 or 52, wherein said energetic beam comprises at least one of electron beam source, laser source, heat source, ion bombardment source, highly focused incoherent light source, microwave, radio frequency, EMF, or any energetic beam that break chemical bonds, or any combination thereof.

57. The apparatus of claim 39 or 52, wherein said communication with said substrate is direct or indirect.